ENERGY/WATER EFFICIENCY AT GLENWOOD ELEMENTARY

by

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Energy/Water Efficiency at Glenwood Elementary

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Abstract

This project focuses on reducing the energy and water footprint of Glenwood Elementary School in Chapel Hill, North Carolina. I inventoried energy and water consumption, modeled costs and benefits of several efficiency upgrades, and implemented those that were possible within a $1000 grant I received from the Kathryn Hoenig Gift.

Glenwood is currently responsible for annual emissions of approximately 398 metric tons of CO2 equivalent and 871 kilo gallons of water consumption. Last year, this energy and water consumption carried a price tag of $80,940, of which most ($75,709) was attributable to electricity and natural gas.

The energy and water upgrades I chose to implement are low-cost with rapid payback periods. They are very cost-effective, though the magnitude of their impact is small compared to Glenwood's energy and water consumption as a whole. These measures will save the Chapel Hill-Carrboro City Schools approximately $750, more than 6800 kWh of electricity, and 44,700 gallons of water annually. Because the upgrades were purchased with grant money, this is essentially an annual $750 donation toward helping the school district meet its educational goals. Implementing such initiatives will also avoid 7,089 pounds of carbon dioxide equivalent (CO_2e) emissions annually. Efficient energy and water use provide financial and environmental benefits, a sometimes elusive partnership.

Approximately $850 of the $1000 grant covered the costs of these upgrades. The remaining funds purchased additional lighting timers for the district to use elsewhere and three Kill-A-Watt energy meters for the Glenwood science teacher (a sustainability advocate) to use in teaching her students about energy efficiency.

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Executive Summary

This Master's Project (MP) focuses on reducing the energy and water footprint of Glenwood Elementary School in Chapel Hill, North Carolina. I inventoried energy and water consumption, modeled costs and benefits of several efficiency upgrades, and implemented those that were possible within a $1000 grant I received from the Kathryn Hoenig Gift.

Analysis of utility bills in the EPA's Portfolio Manager tool[i] indicates that Glenwood is currently responsible for annual emissions of approximately 398 metric tons of CO2 equivalent and 871 kilo gallons of water consumption. Last year, this energy and water consumption carried a price tag of $80,940, of which most ($75,709) was attributable to electricity and natural gas.

The energy and water upgrades I chose to implement are low-cost with rapid payback periods. They are very cost-effective, though the magnitude of their impact is small compared to Glenwood's energy and water consumption as a whole. The following table summarizes the upgrades chosen and their costs and benefits.

Upgrade	Cost	Savings/yr ($)	Savings/yr (kWh/kGal)	Savings/yr (lbs CO2e)	Payback (yr)	Status
1 Vending Machine Miser	$179.00	$131.04	1695 kWh	1766	1.4	Installed
7 Occupancy Sensors	$297.75	$102.88	1331 kWh	1387	2.9	5/7 Installed
4 Outdoor Lighting Timers	$128.98	$121.59	1573 kWh	1639	1.1	Pending
1 Programmable Thermostat	$89.99	$170.49	2206 kWh	2298	0.5	Pending
44 Low-Flow Faucet Aerators	$151.80	$223.37	44.7 kGal	--	0.7	Installed
Total	**$847.52**	**$749.37**	**6805 kWh, 44.7 kGal**	**7089**	**1.1**	

Table 1: Summary of project energy and water upgrades and their costs and benefits.

As shown, these measures will save the Chapel Hill-Carrboro City Schools approximately $750, more than 6800 kWh of electricity, and 44,700 gallons of water annually. Because the upgrades were purchased with grant money, this is essentially an annual $750 donation toward helping the school district meet its educational goals. Implementing such initiatives will also avoid 7,089 pounds of carbon dioxide equivalent (CO_2e) emissions annually, based on US Environmental Protection Agency estimates of average embodied greenhouse gas emissions in North Carolina electricity.[ii] Efficient energy and water use provide financial and environmental benefits, a sometimes elusive partnership.

Approximately $850 of the $1000 grant covered the costs of these upgrades. The remaining funds purchased additional lighting timers for the district to use elsewhere and three Kill-A-Watt energy meters for the Glenwood science teacher (a sustainability advocate) to use in teaching her students about energy efficiency.

Additional savings are possible with larger upfront investments. For example, upgrading existing T-12 lighting with magnetic ballasts to T-8s with electronic ballasts would save approximately $1250 and

16,000 kWh per year, but it has an upfront cost of roughly $4,700. A much simpler upgrade with an even shorter payback period and greater yearly savings would be adding a vending machine controller like the one newly installed at Glenwood to each vending machine in the district. If there were only one cold drink vending machine in each of these schools, there would be 19 potential upgrades. This project would cost just over $3400 and save just under $2500 per year, paying for itself in 1.4 years and saving more than 32,000 kWh annually.

A key barrier to implementing new energy and water efficiency upgrades is the upfront cost and effort, yet these initiatives steadily accrue environmental and financial savings. This hurdle could be overcome by setting aside a portion of each project's annual savings in a fund dedicated to additional retrofits. This idea, first mentioned to me by a student in a presentation Q&A session, helps catalyze continual improvement.

For example, the combined impact of the upgrades I implemented, a T-12 to T-8 retrofit, and installation of district-wide vending machine controllers would have a combined annual benefit of nearly $4500. If even half of this were set aside for further upgrades, higher-ticket initiatives could take off, provide further annual savings, and continue to grow the sustainability fund.

Project Overview

This project involved developing and implementing an energy and water efficiency plan for Glenwood Elementary in Chapel Hill, North Carolina. The first phase of the project involved gathering data about the school and its energy and water use. Data sources included: utility billing records; a facilities assessment describing the key energy and water systems; floor plans; discussions with the district facilities staff, custodian, principal, sustainability consultant, and teachers; and in-person site visits to examine the systems in place and their use.

In the second phase, I identified potential upgrades based on the data gathered in Phase 1. I modeled costs and savings associated with each potential upgrade and submitted the analysis to the district for approval. The upgrades approved were low-flow faucet aerators, a vending machine controller to deactivate refrigeration during unoccupied periods, occupancy sensors for the teachers' workroom and group restrooms, and timers for a subset of the outdoor lights, which are currently turned on 24 hours/day.

Once the upgrades were approved, I researched and purchased upgrade equipment. I submitted the upgrades requiring electrical work to the district for installation, and I installed the upgrade that did not require electrical work (low-flow faucet aerators).

The following report describes in greater detail Glenwood's energy and water systems, the upgrades specified as part of this project, and the potential for future energy and water savings.

A timeline of project implementation stages is shown below.

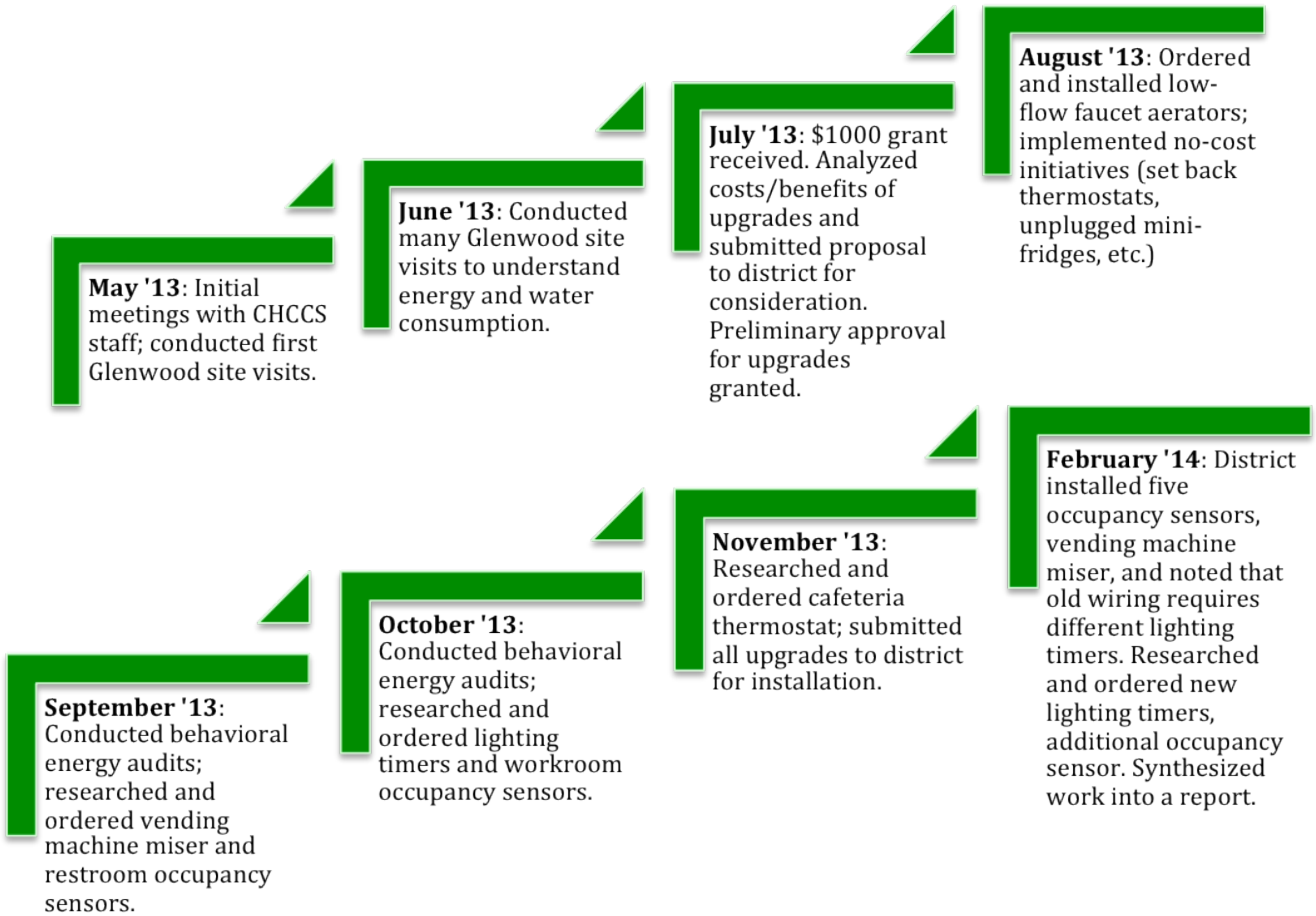

Figure 1: Project implementation timeline.

Overview of Glenwood and its Energy/Water Systems:

Glenwood Elementary is part of the Chapel Hill-Carrboro City Schools. It is located in Chapel Hill, North Carolina (see map at right for location). Glenwood currently enrolls 528 students, up slightly from 517 in 2012-2013.[iii] It is a dual-language school (with Mandarin Chinese), and it has an active after-school program.

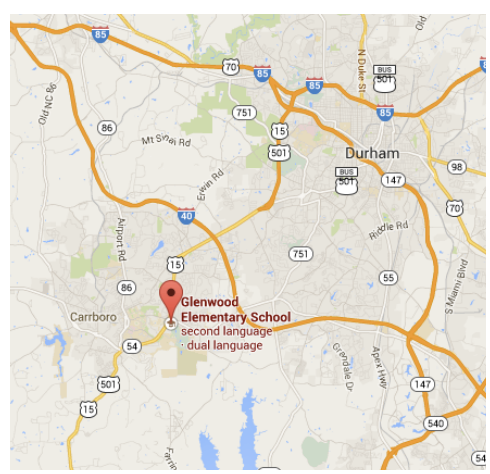

Figure 2: Glenwood Elementary's location in Chapel Hill, North Carolina.

Glenwood is an older school that was built in several stages. The main building and cafeteria were built first (in 1952), followed by a new classroom wing and primary wing in 1954 and 1959, respectively. A multipurpose building that includes a gym and several specialized classroom spaces (art, music, etc.) was added in 1986, and five temporary buildings were added later

(1987, 1990, and 2011).[iv] An aerial view of the school is shown below, with these spaces marked.

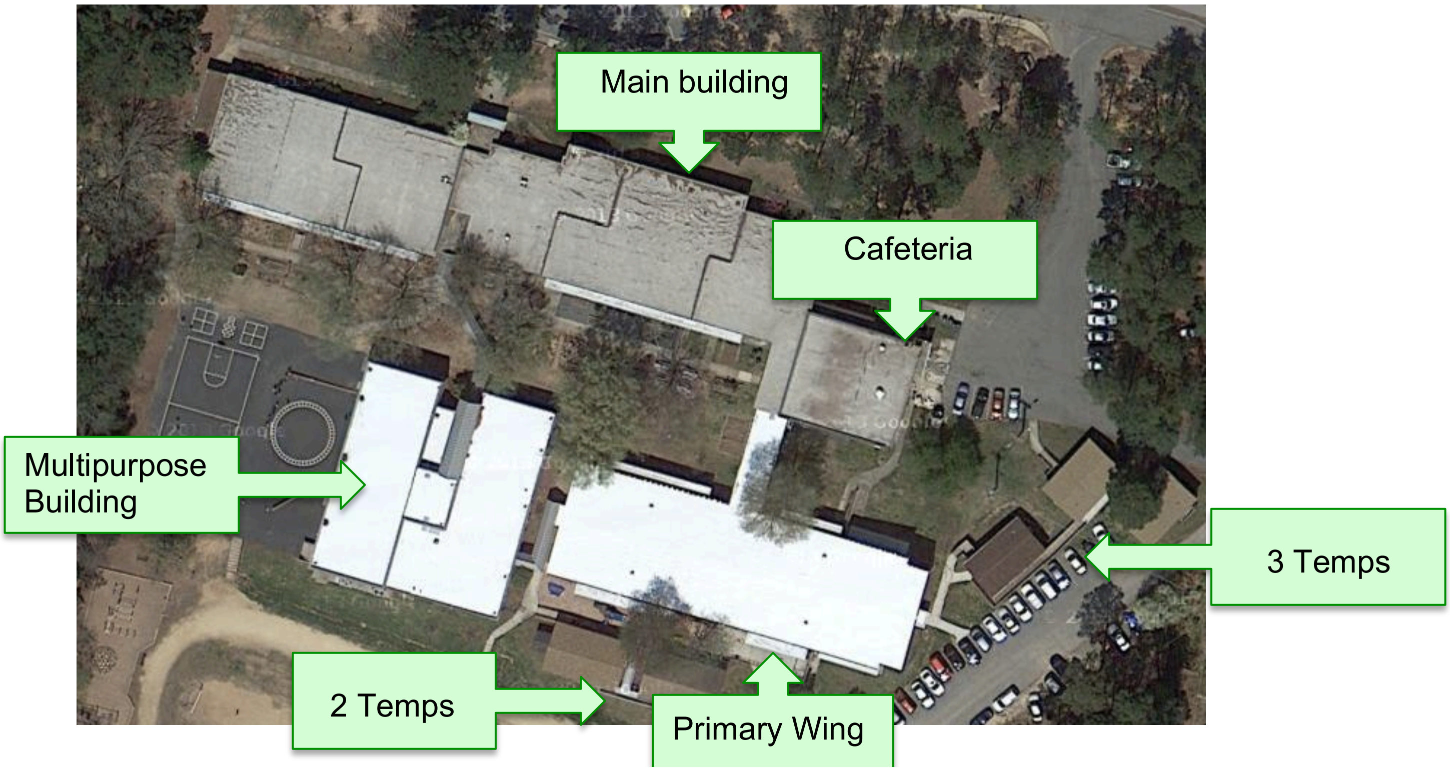

Figure 3: Aerial view of Glenwood Elementary.

The school is built on just over 10 acres, and it has a total building footprint size of 55,372 square feet.[v] Most of the space is dedicated to classrooms and offices. A more detailed breakdown of space uses is shown in the table below to give the reader an idea of how the buildings are used. Throughout this document, I will refer to spaces by these names.

Space Type	# Rooms	Space Type	# Rooms
Classroom	25	Gymnasium	1
Individual Restroom	25	Art Room	1
Office	12	Music Room	1
Storage	7	Media Center	1
Data/Mechanical	5	Cafeteria	1
Group Restroom	4	Kitchen	1
Staff Room	2	Clinic	1
Group Workspace	1		

Table 2: Breakdown of space uses at Glenwood Elementary.

Because the school is quite old, its energy and water systems are not connected to automated controls. The older systems have not been optimized for efficiency, making it a compelling candidate for cost- and carbon-saving energy retrofits. The following is an overview of the school's energy and water systems.

Heating and Cooling:

Most rooms are heated and cooled with a combination of water-source heat pumps and a boiler/cooling tower.[vi] The majority of classrooms have individual units that are controlled with On/Off switches but cannot be adjusted to custom set points. An example of such a unit is shown in the image below.

Several spaces have alternate climate controls. The multipurpose building, library, cafeteria, basement office space, and the temporary buildings all have thermostats. With the exception of the cafeteria unit, they are programmable. The cafeteria unit is an older, analog thermostat (see figure below). It controls a fairly new vertical water-source heat pump.[vii]

Figure 4: Example of classroom HVAC controls.

The thermostats throughout the school are adjusted to a variety of set points; there is not an overarching energy policy that covers these. The table below shows the set points at Glenwood at the time of my June 2013 energy audit. As shown, temperatures varied from 72 to 82 degrees Fahrenheit. All of these spaces were unoccupied at the time of the survey, as it was summer vacation. However, ten of the thirteen thermostats showed the HVAC systems were running. The three that were not running are greyed out in the table. Ending the conditioning of unoccupied spaces is a key energy-saving opportunity area.

Figure 5: Analog thermostat in the Glenwood cafeteria.

Thermostat Set Points	
Room	**Summer Set Point**
Temp 1	On, 72
Temp 2	On, 76
Temp 3	On, 75
Temp 4	On, 72
Temp 5	Off, 82
Gym	On, 72
Shared Workspace a	Off, 76
Shared Workspace b	On, 75
Shared Workspace c	On, 76
Basement Office	On, 74
Basement Room a	On, 75
Basement Room b	Off, 76
Cafeteria	On, 73

Table 3: Thermostat set points at Glenwood in June, 2013.

Lighting:

Most of the school's lighting needs are met by overhead T-8 fluorescent tubes. However, some of the main classrooms and nearly all of the spaces in the multipurpose building are lit with older T-12s. Examples of Glenwood fixtures using these two bulb types are shown below.

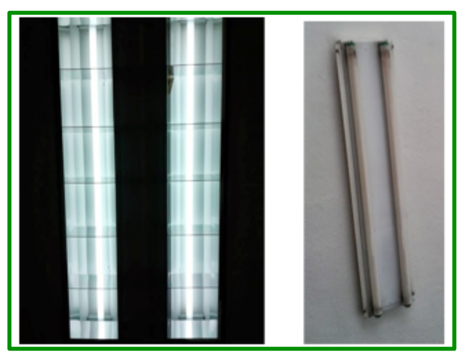

Figure 6: T-8s (left) and T-12s (right) at Glenwood.

The number in the bulb type name refers to the bulb diameter in number of eighths of an inch. T-8s are 8/8 inch in diameter (1 inch), and T-12s are 12/8 inch (1.5 inch) in diameter.[viii] They are very similar in appearance aside from the width, but the T-8s are a much newer, more efficient technology. Much of the difference in efficiency is related to the ballast. A ballast is a device that controls the amount of current that passes to the bulb.[ix] T-12s use older, magnetic ballasts, while T-8s can run on electronic ballasts. In addition to using less energy, electronic ballasts eliminate some irritating effects of magnetic ballasts: flickering, buzzing lights.[x]

The table below shows the locations of the T-12 lamps at Glenwood, as well as the approximate number of lamps per fixture. The number of lamps per fixture figures are approximate because most of the fixtures at Glenwood are covered by light diffuser panels, making it difficult to see how many lamps are used. I used a ladder found in the art room to check several of them manually to improve this approximation. Confirmed values are shown in black lettering in the table, while approximate values are shown in red. In addition to direct observations at Glenwood, the T-12 location data (but not information on the number of lamps per fixture) were informed by correspondence with the district Maintenance Supervisor.[xi]

Space	# 2-Lamp	# 4-Lamp	Total #Fixtures
Hall in front of cafeteria	3		3
Classroom 1		8	8
Classroom 2		9	9
Classroom 3		8	8
Classroom 4		9	9
Classroom 5		8	8
Classroom 6		9	9
Classroom 10		9	9
Classroom 12		9	9
Classroom 14		9	9
Classroom 17		8	8
Temp 1		12	12
Temp 2	1	12	13
Temp 3		15	15
Temp 4		12	12
Music (multi)	2	15	17
Art (multi)		15	15
Stage (multi)		18	18
Girls' Restroom (multi)	3		3
Boys' Restroom (multi)	3		3
Entrance hall (multi)	16		16
Other halls (multi)		8	8
Gym office (multi)		2	2
Gym office closet (multi)		1	1
Storage closet (multi)		1	1
Empty room (multi)		2	2
Offices (multi)		13	13

Table 4: Locations of T-12 lamps at Glenwood.

Quad-tube CFLs are used in the recessed lighting and in a subset of the outdoor lights. A key difference between these and common household helical CFLs is that the ballast is not built into the bulb in a quad-tube light.[xii] Because of this, the bulb must pair with a special fixture rather than being able to screw into a conventional Edison socket. A couple of the outdoor lighting fixtures using these bulbs are shown below (with their plastic covers removed to expose the bulbs).

Figure 7: Outdoor quad-tube CFLs at Glenwood.

A scattering of fixtures still had incandescent bulbs at the time of my initial survey, but a district-wide incandescent bulb replacement initiative has since replaced these with LEDs.[xiii] The lights in exit signs have also been upgraded to LEDs,[xiv] though at an earlier time. A look inside an exit sign at Glenwood in June 2013 confirmed this; see the inside of a sample

Glenwood exit sign below, with LEDs visible.

Figure 8: Inside of a Glenwood LED exit sign.

The last major type of lighting used is metal halide, which is found in the gym.[xv] All of the lights except for a subset of the outdoor lights are switched manually. In fact, the majority of classrooms have multiple switches controlling subsets of the overhead lights; controlling the lights with five separate switches is quite common. Dividing lighting into subsets can allow greater flexibility in that teachers can switch on only the lights needed for a given application. However, it also makes upgrading the system to an automated one more challenging.

Water:

Most Glenwood classrooms have a sink in the main room (with an attached drinking fountain) and a second sink near the restrooms. The majority of these restroom/sink combinations are shared between two adjoining classrooms. An example of this is shown in the floor plan[xvi] at right. The rooms marked ‘3’ are individual restrooms, and the sink is in the space between the rooms (marked ‘2’ in the drawing).

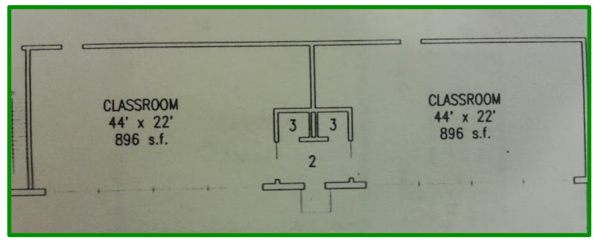

Figure 9: Floor plan excerpt showing Glenwood classroom/restroom layout.

There are also sinks in two sets of group restrooms and the teachers’ workrooms, art room, music room, and nurse’s office. The group girls’ restroom in the main building has been retrofitted with ultra-low-flow fixtures that draw only 0.5 gallons per minute (gpm), but the majority of the faucets draw 2.0 – 2.2 gpm, with some drawing 2.5 gpm. These flow rates are labeled on the faucet aerators throughout the school.

Glenwood toilets are conventional 1.6 gallons per flush (gpf) units, and urinals are a combination of 1.0 gpf and 0.5 gpf (low-flow) units.[xvii]

There are also several drinking fountains throughout the school. During summer 2013 while I was surveying, the outdoor drinking fountain at the corner of the multipurpose building was locked in the “On” position, sending a steady stream of water across the basketball courts. The fountain had been covered with garbage bags in an attempt to stem the leak, but the stream was not contained and continued to flow. This is shown in the photo at right.

Figure 10: Leaking drinking fountain at Glenwood, June 2013.

In addition to the sources mentioned above, the kitchens certainly consume water and energy. Because the kitchens are restricted-access spaces at Glenwood, however, I did not include them in my assessment. Kitchens actually account for only a small fraction of a school’s overall energy footprint,[xviii] but optimizing them with Energy Star equipment and sound policies (i.e. limits on preheating time) could provide straightforward savings.[xix]

Plug Loads:

In addition to the heating, cooling, lighting, and water systems, electronics throughout the school affect energy consumption. The most common at Glenwood are smartboards, desktop and laptop computers, televisions, VCR/DVD players, refrigerators, microwaves, printers, copiers, and stereos. These devices consume electricity both when they are on and when they are off, though consumption is substantially greater while on. Energy savings accrue when occupants use appliances responsibly, including sleeping computers or shutting them down at the end of the day and minimizing the use of high energy-consuming appliances such as personal mini refrigerators. Even Energy Star-certified mini refrigerators consume substantial energy; yearly consumption is approximately 365 kWh on average.[xx]

Mini Refrigerators Left on, Summer 2013	
Room	**Status**
Temp #3	Empty except ketchup packets
Classroom #1	Empty except jug of milk
Classroom #10	Empty
Clinic	Empty

Table 5: Locations of mini refrigerators left on during summer 2013.

There were fourteen mini refrigerators at Glenwood during my June 2013 energy audit. Ten of them had been unplugged for the summer holidays, demonstrating responsible vacation practices. Four of them were still running (see table at left).

Typical Glenwood classrooms have 2-4 desktop computers. They are a mix of generally older models, mostly iMacs and eMacs, though there are also several HP PCs. Glenwood classrooms fitted with iMacs and eMacs are shown below. Most classrooms also have a Smartboard and television.

Figure 11: Typical computer models used in Glenwood classrooms.

Existing technology policy at Glenwood has all Mac computers set to shut down automatically at 4:30 every afternoon.[xxi] This policy saves energy and reduces reliance on teachers shutting down computers themselves.

As mentioned previously, appliances still consume electricity while switched off. This is known as “standby power”[xxii] or “phantom load.” It can be avoided by unplugging electronics or switching off the power strips serving them. To investigate the importance of phantom load at Glenwood, I tested many of the electronics with a Kill-A-Watt meter to determine their relative impact on electricity consumption while switched off but plugged in. The Kill-A-Watt meter measures the power draw of a device at a given instant, and it can also be left monitoring a device over time to track its total energy consumption. The figure at right shows an example of using the Kill-A-Watt meter to test the power drawn by a switched-off Glenwood stereo.

Figure 12: Measuring phantom load of a Glenwood stereo with a Kill-A-Watt meter.

The table below shows the results of these tests for the most common Glenwood classroom electronics. I ran sample calculations to determine the approximate electricity consumption and costs associated with leaving all of the Glenwood devices of these types plugged in over the 2013 summer holidays. Summer break in 2013 was 78 days long (June 8[xxiii] – August 25[xxiv]). The number of devices of each type at Glenwood was estimated through a Glenwood technology survey document[xxv] provided by the Instructional Technology Facilitator and my counts during the summer energy audit.

In reality, many teachers unplugged devices at the end of the school year (though many left them plugged in as well). Accordingly, rather than represent the actual energy and money lost by leaving devices plugged in over summer 2013, the table shows the approximate potential savings from 100% participation in summer vacation shut-down procedures.

Device	Power (W)	Electricity (kWh)	Cost/Unit ($)	Est. # Units	Est. Total Cost ($)
Smartboard	6.4	11.98	$0.96	31[xxvi]	$29.71
iMac	2	3.74	$0.30	21	$6.29
eMac	2.7	5.05	$0.40	31	$12.53
Computer (Other)	2*	3.74	$0.30	19	$5.69
Stereo (off)	0.9	1.68	$0.13	9	$1.21
DVD + VCR	0.45	0.84	$0.07	18	$1.21
TV	2.2	4.12	$0.33	18	$5.93
	Total Electricity	**31.17**		**Total Cost**	**$62.58**

Table 6: Estimated phantom loads for common Glenwood classroom devices in summer 2013.

*Estimated at 2W to provide conservative approximation; only iMacs and eMacs tested with Kill-A-Watt. Many of these “other” computers are HPs. It is also important to note that there are other plug loads at

Glenwood aside from the common examples listed in the table.

Full participation in unplugging these common classroom devices would save just over 31.17 kWh and $60 per summer, indicating that phantom load represents a very small component of total energy use. To put this number in perspective, it is interesting to consider another plug load at Glenwood. In the main teachers' staff room, I used the Kill-A-Watt meter to measure the cold drink vending machine's electricity consumption for one week. It used 62.49 kWh, almost exactly twice the savings from unplugging the classroom devices in the table for the whole summer vacation.

Though phantom load is small, it is easy to avoid, and therefore unplugging devices is a worthwhile habit to practice when leaving for extended time periods. Many electronics at Glenwood are older models, so replacement over time will also cause phantom load to fall. New electronics, in general, consume less phantom load. This is due in part to a 1999 International Energy Agency (IEA) campaign, the "1-Watt Plan," which promotes the production of electronics that minimize this wasted energy.[xxvii]

Behavior:

As mentioned above, several of the classrooms at Glenwood have mini refrigerators. Refrigerators are large plug loads, so it would be most energy-efficient to share larger refrigerators among many teachers rather than have individual classroom units. If units continue to be used in classrooms, it is best to clean them out and unplug them during school vacations and to vacuum the coils[xxviii] periodically. Coils collect dust over time, reducing a unit's efficiency. An example of dust build-up on refrigerator coils at Glenwood is shown in the image at right.

Figure 13: Dusty refrigerator coils at Glenwood.

Behavioral patterns in general are important to examine to determine the potential for savings. For example, if users always turn lights off when they are finished using them, occupancy sensors or lighting timers will not realize any savings. Likewise, if sensors are to be installed or thermostat set points are to be changed, it is important to study occupant behavior to determine the appropriate times that should be considered "peak" and "off-peak." To identify behavioral patterns at Glenwood, I conducted six behavioral audits in September and October 2013 with Assistant Principal Matt Bello.

These audits focused primarily on identifying lighting and computer shut-down patterns at the end of the school day. I conducted each audit between 3:30 and 4:00 PM. On the audited days, an average of 78% of teachers turned off their lights at the end of the day. However, there was significant day-to-day variation, ranging from 93% on a Friday afternoon to only 59% on a Wednesday afternoon (at the same time of day), while many teachers were attending the biweekly staff meeting.[xxix]

Computer shut-down behavior was more consistent across the audited days. On average, 63% of classroom computers were shut down at the end of the day. Results deviated only five percentage points on five of the six sampled days, but Friday was again starkly different. On the Friday sampled, 83% of classroom computers were shut down at the end of the day.

While the sample size is small, the intention of the audit series was to identify broad behavioral patterns and the need (or lack thereof) for interventions. Complete results are shown in the table below.

Date	% Unoccupied Rooms with Lights On	Avg Percent Computers Left On Per Classroom	Day of Week
9/30/2013	13%	41%	Monday
10/1/2013	21%	41%	Tuesday
10/8/2013	30%	43%	Tuesday
10/11/2013	7%	17%	Friday
10/16/2013	41%	41%	Wednesday
10/21/2013	19%	38%	Monday
Average	**22%**	**37%**	
Average Excluding Friday	**25%**	**41%**	

Table 7: Results of lighting and computer shut-down behavioral surveys at Glenwood.

Although most teachers turned off classroom lights, lights in "group" spaces were on every time I checked them during my audits. These spaces are the group restrooms (one set in the main school building and one set in the multipurpose building) and the main teachers' staff room. These behavioral patterns indicate that these group spaces may be priority candidates for occupancy sensors, timers, or other controls.

As mentioned in the plug loads section, most computers are set to automatically shut down at 4:30 PM, though as the assistant principal was available for walk-through audits from 3:30 PM – 4:00 PM, I did not confirm this in person. Energy savings from a campaign to improve teachers' computer shut-down rate at Glenwood would therefore be minimal. The purpose of including computers in the behavioral audit was less about identifying potential savings and more out of interest in human behavior.

Overall Energy and Water Consumption:

The factors described above collectively account for the overall energy and water footprint of Glenwood Elementary. The Chapel Hill-Carrboro City Schools provided utility consumption and cost data,[xxx] which enabled me to quantify this environmental footprint. I tracked the data in the Environmental Protection Agency's Portfolio Manager tool. This is an online system that helps users track electricity, natural gas, and water use in buildings and identify the associated environmental impacts and financial costs.

Analysis of the Glenwood utility bills indicates that the school's operations currently cause approximately 398 metric tons of CO2 equivalent emissions and consume 871 kilo gallons of water per year. Last year, this energy and water consumption carried a price tag of $80,940, of which most ($75,709) was attributable to electricity and natural gas.

To understand these numbers, it is important to compare them to the performance of other buildings. One way to do this is through the Energy Use Intensity metric (EUI). This is the raw energy consumed per unit floor area. 'Site EUI' is the energy consumed at the site itself (in this case, at Glenwood), whereas 'Source EUI' refers to the energy consumed elsewhere to produce energy later used at Glenwood. It accounts for efficiency losses in power generation and transmission. Glenwood's Source EUI in the latest year was 160.3 kBtu/ft^2. The national median, according to Portfolio Manager, is 141 kBtu/ft^2, indicating that Glenwood is slightly less efficient than its peer buildings.

The following figures show how this water and energy consumption varies over time. The first shows Glenwood's monthly water consumption for the period 2009 – 2013. Water consumption follows a clear seasonal cycle, with usage at its lowest point during the summer months when Glenwood is occupied only by administrative and custodial staff. Annual peaks in May and September likely indicate the months with the strongest air conditioning loads during the academic year. Year-to-year variations are likely influenced to a large extent by weather and to a lesser extent by variations in occupant behavior.

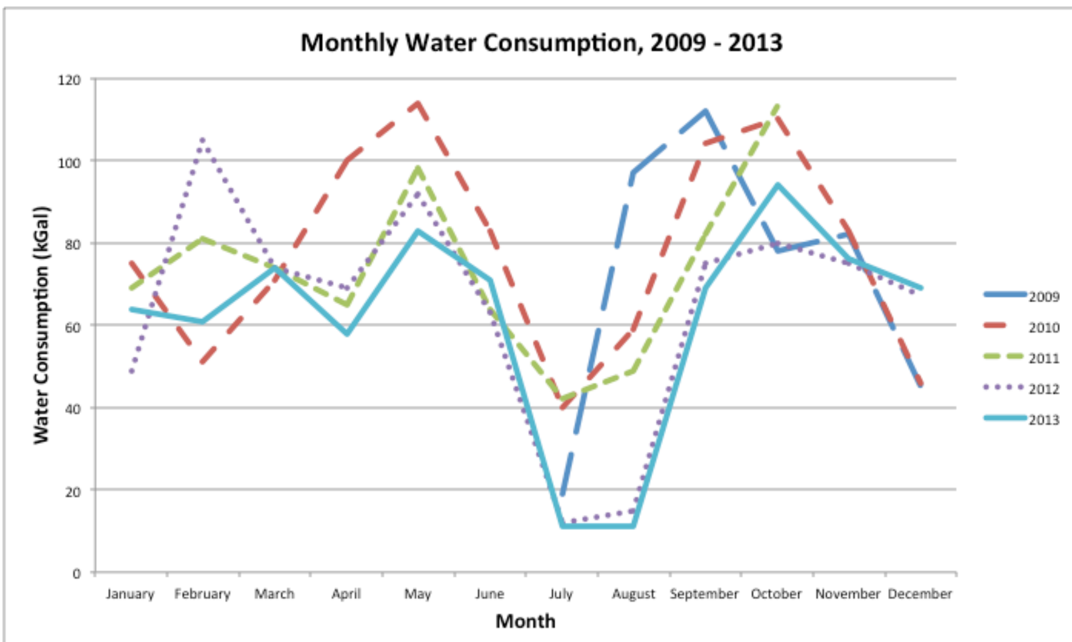

Figure 14: Monthly water consumption at Glenwood, 2009 – 2013.

Electricity consumption shows less seasonal variation, though each year's data shows a peak in both June and September. This is likely because school is in session for at least part of these months, and there are high air conditioning loads. July and August are presumably slightly lower than June and September because, while air conditioning loads would be highest during these months, occupancy is negligible so many other regular loads are not in play. Further, during my mid-June and July 2013 site visits, the on/off HVAC units in classrooms were all switched off. Most spaces controlled by thermostats were being conditioned, but the other spaces were not.

Much of Glenwood's climate control is accomplished by heat pumps, which contributes to the low seasonal variation in electricity consumption; electricity also contributes toward meeting heating demand.

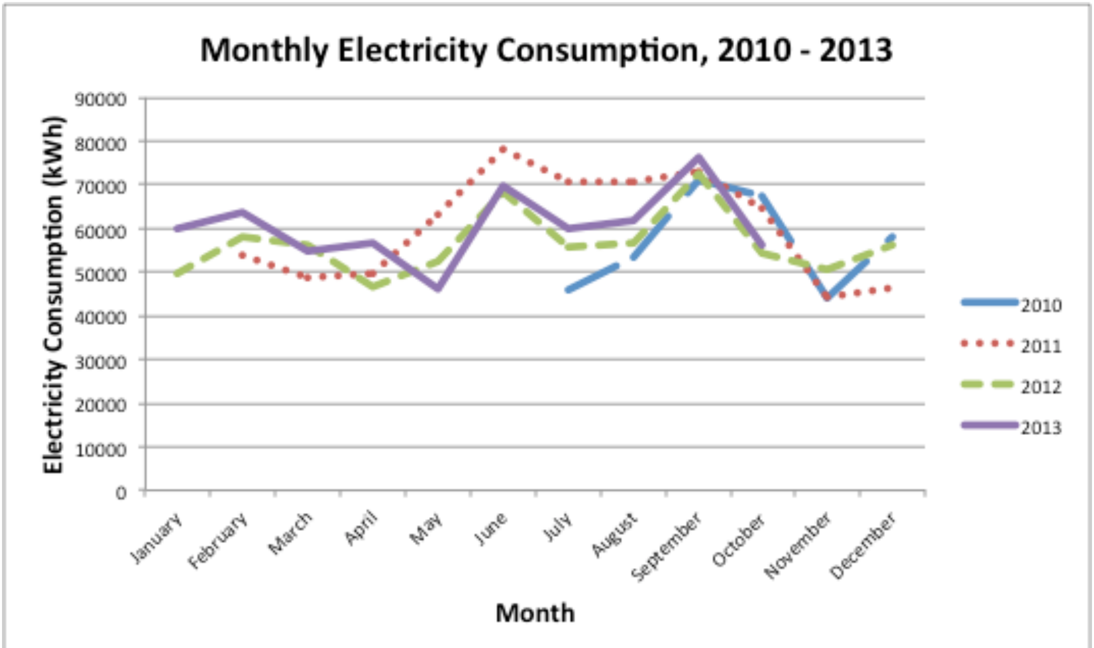

Figure 15: Monthly electricity consumption at Glenwood, 2010 – 2013.

Natural gas contributes to a lesser extent to Glenwood's energy use, and it is used for water heating. The U-shaped seasonal natural gas curves shown in the figure below show higher demand during the winter months. Demand is highest during the winter heating season but remains (at low levels) throughout the year.

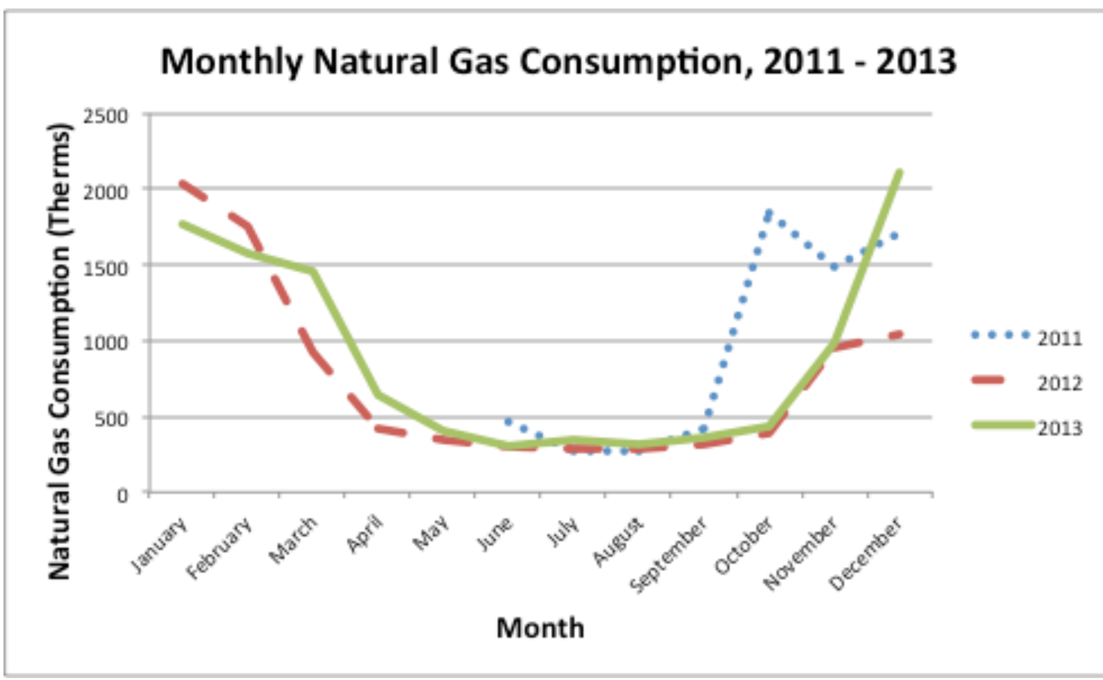

Figure 16: Monthly natural gas consumption at Glenwood, 2011 – 2013.

It is important to note a few data caveats. Glenwood has multiple meters for each utility: two for water, seven for electricity, and two for natural gas. Consumption levels shown in the figures reflect the aggregate consumption from all of the meters. While billing dates were mostly consistent between meters, in a few cases they were off by a few days. Therefore, the consumption curves have slight imperfections on a month-to-month basis. Furthermore, in some cases the billing cycle started and ended mid-month. Therefore, the data attributed to "July," for example, may in fact include partial June or August data.

In the case of the water meters, Glenwood has had one at all times, but the meter was replaced in November-December of 2011. During this transition period, the data were wildly different than other years, indicating the billing data may not reflect actual consumption. I removed these two transitional outliers.

August 2013 electricity figures are missing the data from one of the more minor meters, so the reported value is a slight underestimate. I removed an outlier (January 2011) because it was more than twice as high as any other data points, indicating a likely data reporting error.

Notwithstanding these caveats, the utility billing data reveal important seasonal variations in Glenwood's energy and water use. A building manager could watch the data for major inexplicable outliers that may indicate malfunctioning equipment.

In addition to understanding the general magnitude and seasonal variations in energy consumption, it is also useful to examine how that energy is being used. As described above, energy powers heating and cooling, lighting, plug loads, and cooking. Understanding the relative magnitude of each end use can help indicate which upgrades should be prioritized. The figure at left[xxxi] shows the distribution of energy consumption by end use at a typical school.

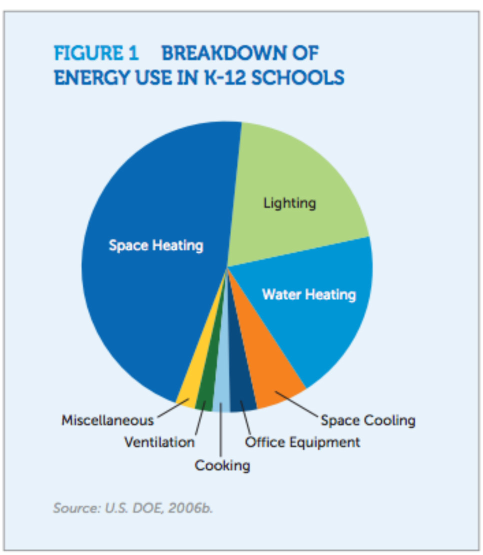

Figure 17: Distribution of energy consumption in schools. ***Source: US EPA***

Space heating and cooling account for the largest end use, followed by lighting and water heating. Indeed, nearly all of the equipment upgrades I included in my project focused on space heating/cooling, lighting, and water conservation.

Analysis and Recommendations

Given Glenwood is operating at somewhat lower efficiency than its peer buildings, there is ample opportunity for energy and water savings. In light of the findings described above, I implemented a set of energy and water efficiency initiatives. These initiatives were a combination of equipment upgrades, policy changes, and identified maintenance needs. A complete overview of these initiatives is shown in the tables below. The first shows general interventions and the second shows equipment upgrades.

Initiative	Type	Location(s)	Notes	Status
Set back air conditioning during summer vacation	Policy change	Temporary buildings, basement workspace	I set back thermostats in unoccupied spaces over the summer. Only set back for part of August due to lag in receiving permission.	Done.
Unplug plug loads during summer vacation	Policy change	All classrooms	I unplugged/cleaned three mini refrigerators and unplugged other classroom devices in August.	Done.
Address broken drinking fountain	Maintenance	Fountain next to multipurpose building	Fountain was running continuously. Informed district; fountain removed.	Done.
Kill-a-Watt Meters	Education	N/A	Provide Glenwood science teacher and sustainability advocate Sally Massengale with three Kill-a-Watt energy meters to teach her students about energy efficiency.	Done.

Table 8: Summary of non-equipment project interventions at Glenwood.

Initiative	Type	Location(s)	Notes	Status
Low-flow faucet aerators (1.5 gpm and 1 gpm, depending on faucet size)	Equipment upgrade	81% of school faucets	All accessible faucets upgraded whose spouts matched one of three standard sizes.	Installed.
Vending machine controller	Equipment upgrade	Teachers' staff room beverage vending machine	Controller has an occupancy sensor that turns off lights and compressor during unoccupied periods.	Installed.
Outdoor lighting timers	Equipment upgrade	Seven quad-tube CFL outdoor lights	Timers set to turn the lights on in the evenings and off in the mornings.	In queue.
Occupancy sensors	Equipment upgrade	Teachers' staff room (3), group restrooms in main building and multipurpose building (4)	Sensors placed in group spaces where the lights were consistently found left on during the behavioral energy audits.	Five installed, two in queue.
Programmable thermostat	Equipment upgrade	Cafeteria	Programmable thermostat to replace old analog model.	In queue.

Table 9: Summary of project-related equipment upgrades at Glenwood.

The following sections provide more information about each of these items.

I: Low-Flow Faucet Aerators

The primary water efficiency initiative I implemented was to upgrade the majority of the faucets by adding low-flow aerators. Aerators are the final "spout" the water passes through before it lands in the sink. They control the pattern and speed of the water. Older aerators have a high flow rate (2.0 – 2.5 gallons per minute), whereas more efficient models have flow rates of 1.0 – 1.5 gallons per minute. Aerators can be twisted on and off by hand or with the aid of a wrench. There are 54 faucets located in accessible spaces at Glenwood, nearly all of which have flow rates of 2.0 or 2.2 gpm.

To determine compatible upgrades, I conducted a detailed inventory of the faucets throughout the school. Aerators come in two major classes (male and female), depending on the orientation of the metal threads that allow them to be twisted on and off of the main faucet fixture. They also come in several sizes, depending on the diameter of the faucet.[xxxii] Luckily, a few fixture types dominate at Glenwood, so I only needed to closely inspect a small sample of the total number of aerators before ordering upgrades.

Two of the original Glenwood aerators are shown in the figure at right. I used the coins pictured to measure the aerator sizes.

Figure 18: Measuring Glenwood aerator sizes with coins.

In mid-August 2013, I installed new aerators in 44 of the 54 classroom, workroom, and bathroom faucets at Glenwood. This represents just over 80% of the eligible faucets. An example of a recently installed new aerator is shown in the figure below.

Figure 19: A Glenwood faucet just after I retrofitted it with a low-flow aerator.

II: Vending Machine Controller

A vending machine is essentially a refrigerator that is constantly running and also lit up. The US Department of Energy's Energy Efficiency & Renewable Energy Program (EERE) lists reducing the energy vending machines and computers consume while not in use on its top ten low-cost energy efficiency recommendations for schools. Vending machines can cost \$200-\$350 per year to operate.[xxxiii] The cost is associated with the electricity needed to constantly refrigerate the contents and light up the display. Vending machine controllers can reportedly reduce energy consumption by 24-76%.[xxxiv]

A vending machine controller is a device that can be attached to the machine. It acts as an occupancy sensor, turning the refrigerator and lights on when there are people about but only cycling on the refrigerator occasionally when no one is there. It is calibrated so people should not notice any difference in the quality of their beverages. I purchased one of these for Glenwood, shown installed in the

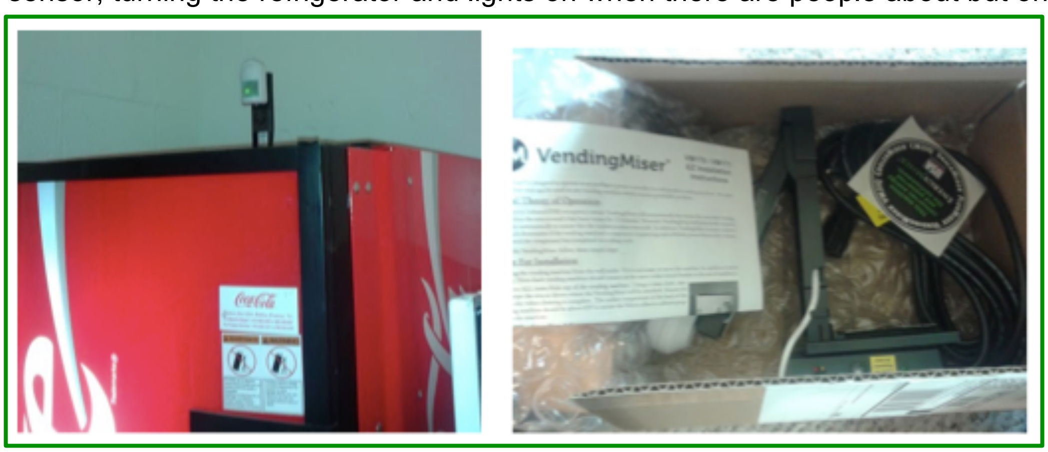

Figure 20: Vending machine controller installed (left) and in the box (right).

Glenwood staff room in the left side of the figure above and in the box in the right side of the figure.

As mentioned in the plug loads overview, I measured the Glenwood vending machine's electricity consumption for one week with a Kill-A-Watt meter (prior to installation of the controller), and found it used 62.49 kWh. Extrapolating this to a year's consumption, the vending machine costs approximately $251 to operate annually, consistent with EERE's estimate noted above.

After the Chapel Hill-Carrboro City Schools electrician installed the vending machine controller in winter 2014, I returned and again measured the electricity consumption. In one week, it consumed approximately 29.89 kWh, less than half of its previous energy use.

While this is an exciting result, there is an important caveat. During both trials, the Kill-A-Watt meter was in place from Friday to Friday. However, during the trial run with controller installed, an unusual snowstorm closed the school on the day I was scheduled to retrieve the meter. I let the meter run for an additional week in order to collect two weeks' worth of data and average it. However, the power had gone out during the storm, interrupting the energy data collection partway through the sixth day.

The Kill-A-Watt meter records the number of hours it has been collecting data, so I was able to adjust the eight days' worth of data to one week. The imperfection in the data is that since the school was closed for two of the weekdays in which it would normally be open, occupancy was artificially low, enabling the new sensor to power down the vending machine more than usual. It is therefore important to note that the savings are somewhat higher than they would be in a typical school week. That said, occupancy is even lower over the summer months, so choosing a perfectly representative week to test would be very challenging.

III: Outdoor Lighting Timers

Seven outdoor lighting fixtures (each holding two quad-tube CFLs) are left on at all times. They are intended to improve safety at night, so they are unnecessary during daylight hours. Lighting timers are included in the EERE low-cost energy efficiency recommendations for schools list.[xxxv] I ordered timers for these lights to ensure they are on only at night.

Installation of these timers is pending because the initial units I purchased required a neutral wire for installation. While modern buildings include a neutral wire, Glenwood is an old school and has older, incompatible wiring. Facilities staff members were not sure of the wiring when I initially inquired about the neutral in November, so we learned in February when the electrician examined it.

Lighting timers that don't need a neutral wire must either be connected to a certain minimum load (often 40W) or have a battery. If the outdoor lighting fixtures were always outfitted with functioning bulbs, the 40W minimum load requirement would be satisfied (each fixture is meant to contain two 28W bulbs). However, as several of the bulbs are burned out or missing, this requirement may not be met. Because of this, I specified new timers that run on a battery. These timers should save approximately $166 per year in avoided electricity costs, paying for themselves in 0.8 years.

I donated the original lighting timers to the district to use in a newer building for a similar purpose.

IV: Occupancy Sensors

As noted during the behavioral audits, lights are often left on in group spaces when no one is around, likely because it isn't clear who is responsible for turning them off. In the case of group restrooms, it can also be unclear if other people are present or not. To address these issues, I ordered occupancy sensors for the four group restrooms and the staff room. Three of these new sensors are pictured, installed, below. From left to right, they are in (1) the girls' restroom in the multipurpose building, (2) the girls' restroom in the main building, and (3) the staff room.

Figure 21: Occupancy sensors installed as part of this project. These are located in restrooms (left and middle) and the teachers' workroom (right).

Two more occupancy sensors will be installed in the staff room this spring. The staff room has seven light switches that each control subsets of the overhead lights, so it is difficult to add automated controls. The one that is currently installed controls a set of overhead T-8s near the vending machines. The two additional ones will control the T-8s over the main workspace. I originally purchased one sensor for this purpose, but the electrician has since noted that a second sensor is required because two switches control this same set of lights. Ultimately, all of the staff room T-8s will be controlled by occupancy sensors. The recessed lights, which account for a much lower share of the lighting, will remain manually switched.

V: Programmable Thermostat

Programmable thermostats allow the user to set different temperatures for different times of day or different days of the week. Most thermostats at Glenwood are already programmable, but the unit in the cafeteria is an older model that can only be set to one temperature. Heating and cooling are the most significant energy users in buildings, so it's important not to heat/cool spaces during unoccupied times. In fact, the Department of Energy's Energy Efficiency & Renewable Energy (EERE) Program lists programmable thermostats as the most effective low-cost energy efficiency recommendation for schools.[xxxvi]

For example, the KEEPS model estimates savings of 1% (versus normal HVAC costs) per degree change in place for 8 hours/day. The KEEPS model recommends set points of 74-76 degrees in the summer and 68-70 degrees in the winter, with summer unoccupied temperatures at 80-85 degrees and winter unoccupied temperatures at 55-60 degrees.[xxxvii] As current cafeteria thermostat set points do not change based on season or occupancy, replacing this thermostat is included in my portfolio of upgrades. The new thermostat could save up to $170 per year, paying for itself in just over half a year.

VI: Set back Air Conditioning During Summer Vacation

Several spaces at Glenwood were conditioned throughout the summer despite being unoccupied. While the on/off classroom units were switched off, spaces controlled by thermostats continued to be cooled. I received permission to set the temperatures in these spaces back to 82-83 degrees Fahrenheit. I set back the accessible thermostats, which are those in the temporary buildings and the offices in the basement.

While I received permission to implement energy-related vacation policies toward the end of the summer vacation, they were in place for approximately two weeks before students returned. It would be good practice to have a regular procedure to set these back on the first day of summer vacation.

VII: Unplug Plug Loads During Summer Vacation

As noted in the plug loads overview, phantom load drawn by devices is relatively small. However, unplugging devices, and therefore avoiding phantom load, is simple and free. I unplugged the common classroom devices (computers, smartboards, stereos, TVs, microwaves, and DVD/VCR players).

During my audit in June, there were four mini refrigerators still running. After receiving permissions to intervene, one of these had already been unplugged and moved. I unplugged, drained, and cleaned the remaining three. While ten of fourteen mini refrigerator owners indeed unplugged theirs for the holidays, having a procedure to check on this and unplug the remaining refrigerators would be worthwhile. Unlike other classroom devices, mini refrigerators are operating in full even when no one is actively using them.

VIII: Address Broken Drinking Fountain

Spotting maintenance issues can have just as much positive impact as installing new equipment. For example, a water conservation measure I helped realize was stopping the previously mentioned continual water leak from the outdoor drinking fountain. I contacted the district facilities department to report the leak, and the drinking fountain was decommissioned. This is shown in the figure below. Note that the drinking fountain has been completely removed.

Figure 22: Leaking drinking fountain at Glenwood (left). As shown in the right panel, the drinking fountain was removed shortly afterward.

IX: Education

Because this project focuses on energy and water efficiency at a school, it is valuable to incorporate an educational component. I purchased three Kill-a-Watt energy meters for the Glenwood science teacher to use to teach her students about energy efficiency. Students can easily plug in these meters to test the power draw and electricity consumption of their classroom appliances, just as I did for this project. It will be a straightforward, practical way to introduce them to the environmental and financial benefits of energy conservation measures.

Costs and Benefits of these Initiatives:

The costs and financial and environmental benefits of these initiatives are shown in the table below.

Upgrade	Cost	Savings/yr ($)	Savings/yr (kWh/kGal)	Savings/yr (lbs CO2e)	Payback (yr)	Status
1 Vending Machine Miser	$179.00	$131.04	1695 kWh	1766	1.4	Installed
7 Occupancy Sensors	$297.75	$102.88	1331 kWh	1387	2.9	5/7 Installed
4 Outdoor Lighting Timers	$128.98	$121.59	1573 kWh	1639	1.1	Pending
1 Programmable Thermostat	$89.99	$170.49	2206 kWh	2298	0.5	Pending
44 Low-Flow Faucet Aerators	$151.80	$223.37	44.7 kGal	--	0.7	Installed
Total	**$847.52**	**$749.37**	**6805 kWh, 44.7 kGal**	**7089**	**1.1**	

Table 10: Summary of energy and water upgrades at Glenwood and their expected financial and environmental savings.

Overall, the project saves approximately $750 per year in utility costs and provides environmental benefits by saving 6800 kWh of electricity and 44,700 gallons of water. This leads to annual greenhouse gas emissions savings of 7,089 pounds of CO_2e, based on US Environmental Protection Agency estimates of average embodied greenhouse gas emissions in North Carolina electricity.[xxxviii]

Recommended Extensions:

The initiatives implemented in this project were low- to no-cost; they were chosen to fit within a $1000 grant budget. Greater energy savings are possible with larger upfront investments.

One key, very cost-effective energy-saving opportunity at Glenwood is a retrofit of the remaining T-12 fluorescent lights to T-8s with electronic ballasts. Based on an approximation of the number of two-lamp and four-lamp fluorescent fixtures remaining in the school (shown in a table earlier in this report) and estimated costs to change out the ballasts and purchase new lamps, such an initiative would cost approximately $4,700 and lead to energy savings of $1250/year. The project would pay for itself in 3.8 years, so it provides a clear net financial benefit in the long run.

Duke Energy, the electric company serving Glenwood Elementary, offers rebates for such upgrades, which greatly reduces the payback period. This and the other parameters that went into estimating the cost, savings, and payback are shown in the appendix.

A much simpler upgrade with an even shorter payback period and greater yearly savings would be adding a vending machine controller to each vending machine in the district. The district has eleven elementary schools, four middle schools, and four high schools.[xxxix] Assuming there is only one cold drink vending machine in each of these schools, there are 19 potential upgrades. This project would cost just over $3400 and save just under $2500 per year, again paying for itself in 1.4 years and saving more than 32,000 kWh annually.

As described in the previous section, it would also be good practice to ensure mini refrigerators are unplugged and thermostats are set back over extended vacation periods. This and other behavioral best practices (i.e. shutting blinds during extended absences) could be encouraged via an email-circulated Eco-Checklist at the end of each school year.

As discussed earlier, with appropriate access permissions, it would be interesting to extend the evaluation into the kitchens. Optimizing them with Energy Star equipment and sound policies (i.e. limits on preheating time) could provide simple savings.[xl]

A key barrier to implementing new energy and water efficiency upgrades is the upfront cost and effort, yet these initiatives steadily accrue environmental and financial savings over time. A key way to overcome this initial hurdle would be to set aside a portion of each project's annual savings in a fund dedicated to additional retrofits. This idea, first mentioned to me by a student in a presentation Q&A session, helps catalyze continual improvement.

For example, the savings in one year from the upgrades I implemented are approximately $750. The annual savings from upgrading the Glenwood T-12s would be approximately $1250, and the savings from retrofitting the vending machines are nearly $2500/year. Their combined impact in one year would be over $4500. If even half of this were set aside for further upgrades, higher-ticket initiatives could take off, provide further annual savings, and continue to grow the sustainability fund.

Appendix: Calculations

Greenhouse Gas Emissions Savings

According to the US Environmental Protection Agency's eGrid electricity emissions factors (2009 data), electricity production in North Carolina causes average carbon dioxide equivalent emissions of 1,041.73 lbs per MWh.[xli] Multiplying this emissions factor by the savings from project initiatives (6,805 kWh, or 6.805 MWh) yields greenhouse gas emissions savings of 7,089 lbs of CO_2 equivalent per year.

Cost/Benefit Models for Each Initiative

Estimated costs and benefits for the retrofits recommended are based on Excel spreadsheet models. The following tables show the parameters and assumptions that went into each calculation.

Vending Machine Miser

Current Energy Consumption	
kWh/week (measured)	62.49
kWh/year	3249.48

Future Energy Consumption	
New kWh/week (measured)	29.89
New kWh/year	1554.28

Cost to Run	
$/kWh	$0.08[xlii]
Current $/year	$251.18
Future $/year	$120.15

Cost of Controller	
Cost (actual purchased cost)	$179

Savings	
Savings/year ($)	$131.04
Savings/year (kWh)	1695
Payback period (years)	1.4

Low-Flow Aerators

Small Aerator: Details	
# Units	12
Cost/unit (actual cost)	$3.29
Shipping/tax (actual)	$13.46
Total cost (actual)	$52.94
Flow rate (gpm)	1.5

Large Aerator: Details	
# Units	32
Cost/unit (actual cost)	$2.24
Shipping/tax (actual)	13.74
Total cost (actual)	$85.42
Flow rate (gpm)	1.0

Upgrade Details	
Total # faucets	54
# Faucets upgraded	44
% Upgraded	81%
Average upgraded flow rate (gpm)	1.31
Est. avg previous flow rate (gpm)	2.10
Est. savings per minute (gpm)	0.78

User Parameters	
Number of students	528[xliii]
Number of staff	90[xliv]
Total # people	618

Water Consumption Estimates	
Handwashes/person/day	2
Total handwashes/day	1236
Days per school year	185
Total handwashes/year	228660
Minutes/handwash	0.25[xlv]
Total minutes of handwashes/year	57165

Costs	
Total cost (aerators)	$138.36
Cost/kGal water	$5.00[xlvi]

Savings	
Total est. savings/year (gallons)	44673
Total est. savings/year (kGal)	44.7
Total cost savings/year ($)	$223.37

Outdoor Lighting Timers

Bulb Characteristics	
Bulb type	CFL quad tube
Watts/bulb (noted on bulb)	28
# of bulbs (minus burnt out)	11
Hours/day (current)	24
Hours/day (future)	10

Energy Consumption	
kWh/day (current)	7.4
kWh/month (current)	224.7
kWh/day (future)	3.08
kWh/month (future)	93.6

Cost to Run	
$/kWh	$0.08
$/month (current)	$17.37
$/month (future)	$7.24

Cost of Timers	
$/timer (actual cost)	$28.41
Number of timers	4
Total timer cost	$113.64
New plate cost (actual cost)	$3.01
Number of plates	4
Total plate cost	$12.04
Tax (actual tax)	$3.30
Total cost	$128.98

Savings	
Savings/month ($)	$10.13
Payback period (years)	1.1

Savings/year ($)	$121.59
Savings/year (kWh)	1573

Programmable Thermostat for Cafeteria

Characteristics	
Current temperature (F) (observed)	73
Savings per degree setback (heating)	3%[xlvii]
Savings per degree setback (cooling)	6%[xlviii]
$/kWh	$0.08
kWh/square foot (heating)	0.8[xlix]
kWh/square foot (cooling)	3[l]
Cafeteria area (square feet)	2040[li]
kWh (heating)	1632
kWh (cooling)	6120
Current cost to heat/cool	$599.23

Cost of Thermostat	
Cost of programmable thermostat (actual cost)	$89.99

Savings	
Number of school days/year	185[lii]
Number of non-school days/year	180
Savings from setback to 70 (heating)	2%
Savings from setback to 78 (cooling)	5%
Savings from summer setback to 85 (cooling)	14%
Savings from weekend setback to 85 (cooling)	6%
Savings from weekend setback to 62 (heating)	3%
Total savings	28%
Savings/year ($)	$170.49
Payback period (years)	0.53
Savings/year (kWh)	2206

Occupancy Sensors: Girls' Restroom (Gym)

Characteristics	
Number of fixtures (2-lamp T-12s)	3
Watts/fixture	78[liii]
Total Watts	234
Current time on (hours)	1480*
Current Energy Usage	
Current kWh/year	346.32
$/kWh	$0.08
Current cost to run/year	$26.77
Savings	
Estimated savings	60%[liv]
New cost to run/year	$10.71
Costs	
Occupancy sensor cost (actual cost)	$40.37
Wall plate cost (actual cost)	$2.48
Total cost	$42.85
Savings	
Savings/year ($)	$16.06
Payback period (years)	2.67
Savings/year (kWh)	208

*This calculation assumes the bathroom lights are on 8 hours/day during school days. The actual figure may be higher or lower. Please note that this is an example calculation; my Excel spreadsheet has one of these tables for each of the five rooms fitted with occupancy sensors.

T-12 to T-8 Lighting Upgrade

Fixtures and Lamps	
Number of 4-lamp fixtures	212
Number of 2-lamp fixtures	28
Number of new T-8 lamps	904
Watts/T-12 4-lamp fixture	156[lv]
Watt/sT-12 2-lamp fixture	78[lvi]
Watts/T-8 4-lamp fixture	106.7[lvii]
Watts/T-8 2-lamp fixture	62[lviii]

Costs	
Cost per electronic ballast (4-lamp)	$17[lix]
Cost per electronic ballast (2-lamp)	$15[lx]
Cost per T8 lamp	$4.75[lxi]
Duke Energy rebate/4-lamp fixture	$16.00[lxii]
Duke Energy rebate/2-lamp fixture	$8.00[lxiii]
Total Duke Energy rebate	$3,616.00
Net total cost after rebate	$4,702.00

Savings	
$/kWh	$0.08
Current time on (hours/year)	1480
Current kWh/year	52179
Future kWh/year	36047
Current cost/year	$4,033.43
Future cost/year	$2,786.47
Savings/year	$1,246.96
Payback period (years)	3.77
Savings/year (kWh)	16131

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